Water infiltration rate in the soil under different uses and covers in the Poxim River basin, Sergipe, Brazil

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Abstract

Watersheds are units of planning and environmental management having a great importance in the management of water resources and their use. To this end, knowledge about the soil's physical and water attributes is of paramount importance in the context of water dynamics in aquifer recharge areas. Water infiltration rate into the soil is considered an important variable in the hydrological cycle, as the increase in this process can lead to a reduction in erosion and consequently greater groundwater recharge. Thus, the present work aimed to evaluate the soil water infiltration rate in the phytophysiognomy of the Poxim River basin in the State of Sergipe, in the agriculture, eucalyptus and forest areas, and to observe the effect of the infiltration water rate in areas of no-till, minimum and conventional cultivation. The soil water infiltration rate was obtained through the use of double cylinder infiltrometer and estimated through the mathematical models of Kostiakov, Kostiakov-Lewis, Horton and Philip. When making comparisons between the models for estimating of soil water infiltration rates, the Horton model showed a better fit compared to the other models used, and the type of soil cover that obtained the highest infiltration rate was the forest. No-till areas provided higher water infiltration rates in the soil, contributing to greater groundwater recharge.

Keywords: Horton, No-Tillage, Eucalyptus, Forest, conventional cultivation.

1. Introduction

The problems related to the water availability amount are real in some areas of the planet, motivated by the edaphoclimatic characteristic as well as anthropic action. Thus, attention is focused on the possibilities of solutions that aim to structure the capacity of the natural replenishment of water sources in these regions environmentally.

In Brazil, the difficulties in environmental application and management of water resources were even greater, as the management bodies were challenged by the limitations of their established accusations. For this reason, there was a need to create more active and rigorous policies for the protection of water resources that aimed at planning to ensure quality and quantity of water for various types of use. In view of this, Law

9.433/97 was created which established the watersheds as drainage physiographic areas considered as representatives of the environmental planning units, being characterized both by the functionalities of its elements as well as by the integration of the entire land area. However, even with the importance of the functional knowledge of the watersheds, failures or lack of hydrological monitoring are present.

It is necessary to know the soil water infiltration in the management of watersheds in the area of water resources to solve issues related to water conservation. Characterized as a system of water entry through the soil surface, the infiltration favors the wetting of the soil, so there is a decrease in the rate of water entry into the soil, subsequently reaching a lower constant value, called the basic infiltration rate. The soil water infiltration is defined by the use, type and slope of the area. The dynamics of water in the soil is a reflection of changes in the soil.

Thus, considering the importance of obtaining greater knowledge about water recharge in the groundwater by the characteristics of soil water infiltration, this work aimed to evaluate the soil water infiltration rate in the phytophysiognomy of the Poxim River basin in the State of Sergipe under different soil use conditions.

2. Material and Methods

2.1 Characterization of the Study Area

The research was carried out in the Poxim River basin, which comprises an area of 346.72 km2, located in the eastern portion of the State of Sergipe, between the geographic coordinates of 10°55' and 10°45' South latitude and 37°05' and 37°22' West longitude (Ferreira et al. 2011).

The watershed is characterized by type A's Tropical climate (rainy with dry summer), according to the Köppen classification. The average annual rainfall is 1,200 mm, with concentrated rainy season from April to September (Ferreira 2015) and average temperature 23°C in the coldest months (July and August) and 31°C in the hottest months (December and January) (Silva 2001).

Inserted in the Atlantic Forest biome, currently the Poxim river basin is restricted to mangroves in the estuaries, restinga vegetation on sandy soils and little remnants of the Humid Tropical Forest (BRAZIL 2001). Litolic Neosolum, Quartz Geosolum, Gleissolum and the predominance of Yellow Red Argissolum or Ultisol for USDA soil taxonomy are present in this area.

To carry out the research, images from the GeoEye Satellite were initially obtained for making maps of soil use and occupation in the watershed, and later field visits were carried out in these areas located on the maps.

The technical methodological procedure based on the mapping approach developed by Moreira (2011) was used based on the high spatial resolution images captured from Google Earth, in addition to the visual interpretation technique described by Novo (2008). The acquisition of the GeoEye Satellite images of the watershed was carried out with support from Google Earth 7.1 software. To cover the watershed boundary, a set of six scenes was required, which were saved in JPEG format. The georeferencing parameters were inserted in the images, then a mosaic of the converted and recorded scenes in the Universal Transverse Mercator (UTM) coordinate system, 24 L spindle and Datum WGS84 and export the file in GeoTIFF format. During the process of interpretation, detection, recognition, analysis, deduction, classification and evaluation were performed almost simultaneously. Furthermore, the visual interpretation was based on seven characteristics of the image in the process of information extraction, such as: tone/color, texture, pattern, location, shape, shadow and size (New 2008), allied to the methodological support to the orientation of the Technical Manual of Soil Use of IBGE (2006), as can be seen in Figure 1.

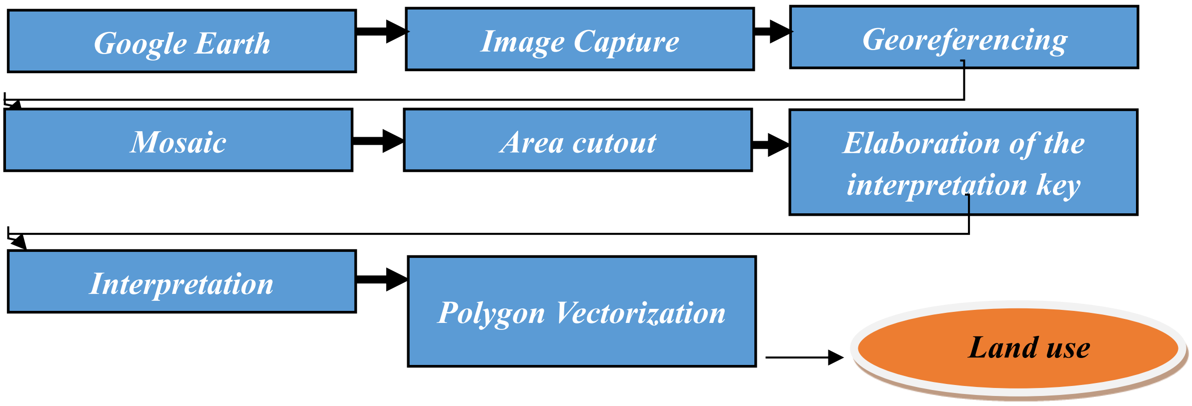

Figure 1: Flowchart of the operations performed to create the soil use map of the Poxim River basin, in the State of Sergipe, Brazil.

Based on the recognition of the study area through high resolution images, six classes of soil use and coverage were identified in the Poxim River basin. Native vegetation, water bodies, agriculture, exposed soil, pasture and urban area were identified on the map. The map of soil use and vegetation coverage of the Poxim River basin can be observed in Figure 2. The total area for each class mapped in the watershed can be seen in Table 1.

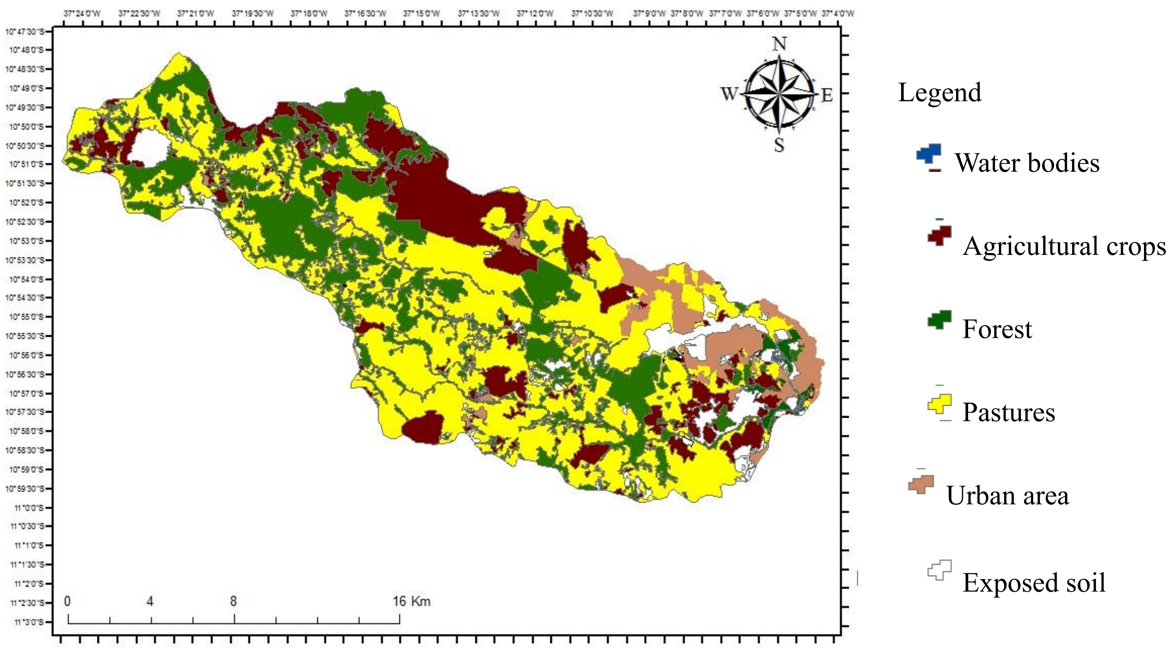

Figure 2: Map of soil use and vegetation cover of the Poxim River basin in Sergipe State, Brazil.

Table 1: Soil use classes in the Poxim River basin, Sergipe State, Brazil

Soil use classes	Area (km^2)	Percentage (%)
Pastures	158.81	45.80
Forest	91.52	26.39
Agricultural crops	58.36	16.83
Exposed soil	18.93	5.45
Urban area	18.63	5.37
Water bodies	0.47	0.13
Total	346.72	

2.2 Field sampling

The soil water infiltration tests in the soil and the determination of moisture, density and soil texture were reported in the areas of forest, eucalyptus and agricultural cultivation, using the sunflower (Helianthus annuus L.) as a cover plant in succession to corn (Zea mayes L.), which has been cultivated in three management systems (no-tillage, conventional cultivation and minimum cultivation). No-tillage has consisted of not turning over the soil. Conventional cultivation was composed of gradation with disc levelling + ploughing with disc plough + gradation. The minimum cultivation was composed of one or two gradations with disc levelling gradations, and the second gradation was only carried out when there was a considerable incidence of invasive plants.

Deformed soil samples were collected for moisture determination by the gravimetric and texture method (EMBRAPA 2013), as well as indeformed soil samples for soil density determination by the volumetric ring method, at depths of 0 - 10 and 10 - 20 cm. Soil texture analysis was performed by the pipette method (Table 2).

Table 2. Texture of a Yellow Red Argissolo in the different types of soil use in the Poxim river basin, from the surface layer of (0 - 20 cm)

Soil use	**Texture (%)**		
	Sand	**Clay**	**Silte**
Forest	70.61	15.13	14.26
Agricultural	68.76	18.00	13.24
Eucalyptus	64.95	16.55	18.50

2.3 Soil water infiltration test

Soil water infiltration tests were performed using the double cylinder infiltrometer methodology (Brandão et al. 2009). This test consists in using two concentric cylinders, the largest with a diameter of 50 cm and the smallest with a diameter of 25 cm, both with a height of 40 cm (Figure 3). The infiltration was determined by measuring the height of water infiltrated into the soil by the smaller cylinder (internal) in successive times of readings.

Figure 3. Set of double cylinder infiltrometer.

The tests were performed until the infiltration rate became approximately constant over time. According to the experimental tests performed in the areas, the times for each reading of 2, 5, 10, 20, 20 minutes were established.

The soil water infiltration rate was estimated by means of empirical and theoretical models of Kostiakov (1932), Horton (1940), Kostiakov-Lewis and Philip (1957).

2.3.1 Kostiakov model

The empirical equation is based on the infiltration of the Kostiakov model developed in 1932, this one in the form of the connection of the field data curve.

$$I = kt^{\propto} \tag{1}$$

wherein:

I = infiltration;

t = time; and

k e α = constants that depend on the soil and its initial conditions, that is, they depend on the characteristics of the soil, such as soil texture, moisture content, density and other parameters.

2.3.2 Horton model

This equation developed by Horton (1940) has been widely used in hydrological models, as it reflects the laws and fundamental principles of soil physics.

$$i = i_f + \left(i_i - i_f\right)e^{-\beta t} \tag{2}$$

wherein:
i = infiltration rate;
i_f = the final balance or capacity of the infiltration rate;
i_i = the first infiltration capacity (t = 0); and
β = a constant that represents the rate of decrease of the infiltration rate capacity.

2.3.3 Kostiakov-Lewis ou Kostiakov modified

This equation was developed to eliminate the deficiency of the infiltration rate to tend to zero when time tends to infinity.

$$I = kt^{\propto} + i_f t \quad (3)$$

wherein:
I = infiltration;
t = time tending towards infinity; and
i_f = the equilibrium (the constant final infiltration rate).

2.3.4 Philip model

Combined with the Darcy equation for unsaturated media and with the continuity equation one arrives at a second order partial non-linear differential equation, also called the Richards equation.

$$I = \frac{1}{2} S t^{-1/2} + F \quad (4)$$

wherein:
F = gravity contribution constant for a ground movement; and
S = determined by linear regression of I as a function of $t^{-1/2}$.

2.4 Statistical analysis

Residual mass coefficient (RMC) (Eq. 5), adjustment coefficient (AC) (Eq. 6) and efficiency (EF) (Eq. 7) were used to evaluate the performance between the values of the water infiltration velocity in the soil determined with infiltrometer cylinder and the values estimated by means of empirical and theoretical models.

$$RMC = \frac{(\sum_{i=1}^{n} O_i - \sum_{i=1}^{n} P_i)}{(\sum_{i=1}^{n} O_i)} \quad (5)$$

$$AC = \frac{\sum_{i=1}^{n} (O_i - \bar{O})^2}{\sum_{i=1}^{n} (P_i - \bar{O})^2} \quad (6)$$

$$EF = \frac{\left[\frac{\sum_{i=1}^{n} (O_i - \bar{O})^2}{\sum_{i=1}^{n} (O_i - \bar{P})^2}\right]}{\sum_{i=1}^{n} (O_i - \bar{O})^2} \quad (7)$$

wherein:

O_i = observed values;

P_i = estimated values;

n = number of observations;

$\bar{O}$ = arithmetic mean of observations; and

$\bar{P}$ = arithmetic mean of the estimated values.

The water infiltration rate was evaluated under three types of soil management (no-till, conventional and minimum cultivation), two soil cover (forest and eucalyptus) and the empirical and theoretical models in a subdivided plot scheme, according to an entirely randomized design with three repetitions. The results were submitted to the F test of variance analysis and the means compared by applying the Tukey test, at 5% probability.

3. Results and Discussion

The water infiltration rate curves are observed over time for no-till, minimal cultivation and conventional cultivation areas. The curves obtained in the tests describe well the process of soil water infiltration in the area (Figure 4).

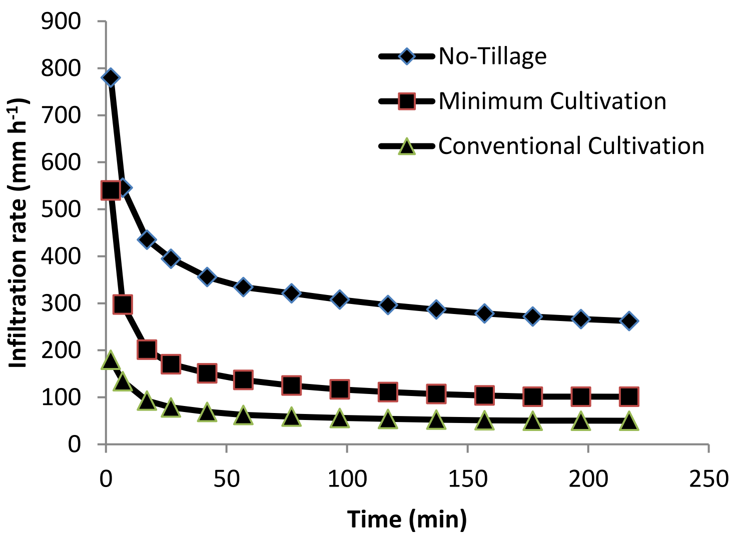

Figure 4. Curves of mean values measured of the soil water infiltration rates in no-tillage (NT), minimum cultivation (MC) and conventional cultivation (CC), as a function of the accumulated time in the agricultural area.

It was verified that the basic infiltration rate for the no-tillage area was 220 mm h^{-1}. The result found in the present work is in accordance with those obtained by Cunha et al. (2011) who obtained the stabilization of the infiltration rate at 160.32 mm h^{-1} when evaluating the infiltration of water into the soil submitted to the no-tillage system.

These high values of soil water infiltration rate can be motivated by the excellent drainage characteristics in the respective soils, since the no-tillage system allows the maintenance of plant remains. These no-tillage areas are characterized by the non-return of the soil, or seja¸ by the permanence, for varying periods, of the residues of the previous crop and of the plant on the surface, which leads to an increase in the total porosity of the area, especially the macroporosity that exerts a great influence on the infiltration of water into the soil. It is noted that the effect of plant cover provides sufficient protection for the dissipation of the kinetic energy of raindrops, offering barriers to the sealing of the soil surface and consequently to the runoff of water, improving the soil water infiltration (Santos and Pereira 2013; Montenegro et al. 2013; Nicholls and Altieri 2012; Nunes et al. 2012).

Almeida et al. (2016) concluded that no-tillage is an efficient system for soil conservation or its recovery and in it, the organic matter assigned, improves the soil's physical conditions.

Costa (2013) stated that porosity values lower than adequate can be found, but due to good connectivity between the pores, this situation is not restrictive and there is good water conduction. For Silva et al. (2006), the soil condition provided by its management is a factor that clearly influences the soil water infiltration. Farias (2015) mentions that the water infiltration rate is one of the best parameters to assess soil structural quality. Stefanoski et al. (2013) further clarifies that, when discriminating soils with signs of degradation, the indicators of soil physical quality show the need to adopt systems that favor soil structuring, such as those that raise the levels of organic matter.

The minimum cultivation system presented an intermediate value between no-tillage and conventional cultivational systems, with the basic infiltration rate stabilizing when reaching the value of 82 mm h^{-1}, which was already predicted, since the reduction in the use of agricultural implements in the respective area allows for a better infiltration rate, i.e., there is an inverse proportionality, so that the greater the soil turning over through agricultural mechanization, the lower the soil water infiltration rate. According to Figueiredo et al. (2008), this soil management and preparation system consists of minimal soil development, reducing the potential for erosion by not disintegrating the soil and by maintaining vegetation at the surface, maintenance of moisture and water retention capacity by the soil, because of the non alteration of the structure and capillarity of the soil and maintenance of biological balance in the soil. For Blainsk et al. (2008), the soil use and management systems must maintain the capacity of the soil to perform the physical functions for the growth of the plants' roots, as well as favor the water supply. Soil losses due to erosion, reduction of organic matter, compaction, reduction of porosity, and permeability, are some of the consequences of poor use of the soil resource.

This investigation disagreed with the results found by other authors (Cunha et al. 2015; Kamimura et al. 2009; Pinheiro et al. 2009) when they studied the infiltration rates in different soil management systems (conventional, minimal and no-tillage), they concluded that minimal cultivation provided higher values of soil water infiltration rate. This difference can often be associated with different soil classes, contribution of organic matter, soil quality, different climate and the time of use in the areas. Veiga (2005) states that the continued use of soil management systems determines changes in soil properties, whose intensity depends on the time of use.

The conventional cultivation system obtained a basic infiltration rate of 42 mm h^{-1}, and at the beginning the infiltration rate was 180 mm h^{-1} and soon afterwards it suffered a sharp decrease from the first seven minutes. This decrease was basically due to the traffic of agricultural machinery as well as the use of disc plough and levelling harrow, implements used to mobilize and incorporate plant residues in soil preparation

(Figure 4). When preparing the soil, the permeability of the superficial layers tends to increase temporarily, due to the breaking of the structure of this strip fact that, Costa et al. (2015) in his study on water movement and soil porosity of a sub-basin in the northwest of São Paulo State, states that, normally, soil development promotes a temporary increase in porosity, and consequently of water movement in the soil. Soon after, there is a reduction that is motivated by the compaction at the bottom of the furrow, this compacted layer that develops just below the plowed or gridded strip, causes a sealing in the soil, making it difficult for the water to infiltrate these areas.

Bertol et al. (2004) state that conventional cultivation degrades physical properties, because the revolving breaks the aggregates, compacts the soil below the prepared layer and leaves it uncovered. According to Silva et al. (2014), the physical characteristics of the soil are directly linked to its water infiltration capacity and that, due to the mechanization process, it is necessary to analyze deeper layers that correspond to the whole profile explored by the roots in order to obtain greater certainty of water availability for the crops. The result of this research differs from that found by Viana et al. (2015), who found higher values of basic infiltration rate (234 mm h^{-1}) in areas with conventional cultivation system.

Santos et al. (2020) evaluating the use of different infiltrometers to assess environmental damage caused by different soil uses, they observed that different uses and soil cover influenced the rate of soil water infiltration obtained by different infiltrometers.

Figure 5 shows the water infiltration curve in the soil determined from the data collected with the double cylinder infiltrometer for the eucalyptus area. The basic infiltration of water into the soil in this area presented an infiltration rate of 50.01 mm h^{-1}. The areas with eucalyptus plantations allow improvements, due to higher concentrations of organic matter, as well as the large amounts of roots present that promote the approximation of particles, through the constant absorption of water in the soil profile. According to Prevedello (2012), eucalyptus forest systems contribute to the improvement of structural quality, as they favor the formation of continuous pores, important for adequate aeration, retention and water conduction.

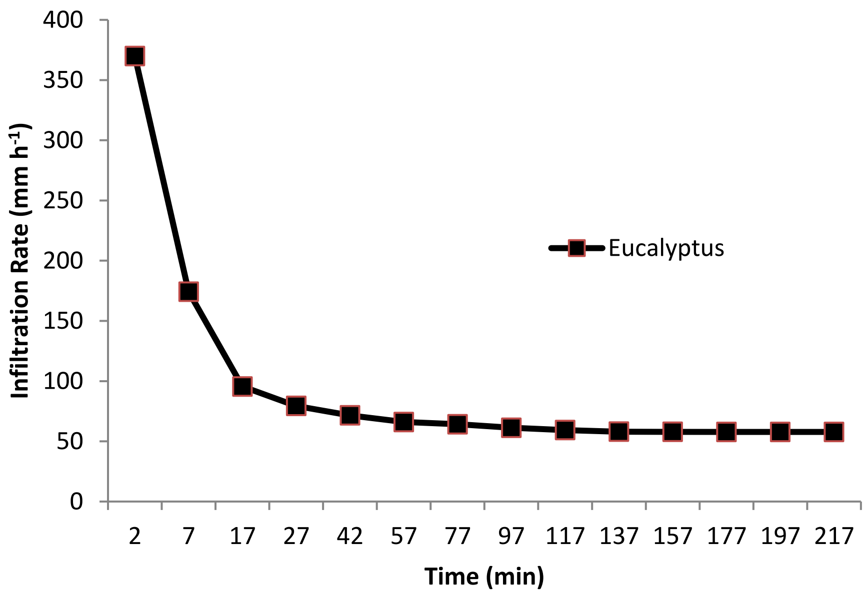

Figure 5. Soil water infiltration rate in the eucalyptus area.

There was a very sharp decrease in the first seven minutes of the infiltration test, reducing by half (Figure

5). This may be motivated by the intense passage of machinery in the eucalyptus area, which possibly caused a compaction in the soil layers, thus leading to low water infiltration capacity in this area, being possible to affirm that there is a high susceptibility to the occurrence of surface runoff.

Szymczak et al. (2014) warn that the weight and movement of the machines, combined with the improper soil moisture condition, are the main causes of structural soil degradation, verified mainly by changes in their physical properties. The same authors also concluded that harvest operations impact the soil up to a depth of 10 cm, causing compaction in the traffic lines of the machines. Morais et al. (2012) still point out that the excessive traffic of agricultural machinery causes soil compaction and thickening, which ultimately translates into high soil density values.

The soil water infiltration rate in the forest area (Figure 6) was classified as very high, reaching the value of 273 mm h^{-1}. This result disagrees with the findings of Marcatto and Silveira (2015) who obtained basic water infiltration rates in the soil ranging from 2100 to 1560 mm h^{-1} in the Pirapó River basin in the state of Paraná. These results may be associated with the variety of plant species present in forests, with different types of root systems, and the presence of macrofauna found in these soils, close to the surface.

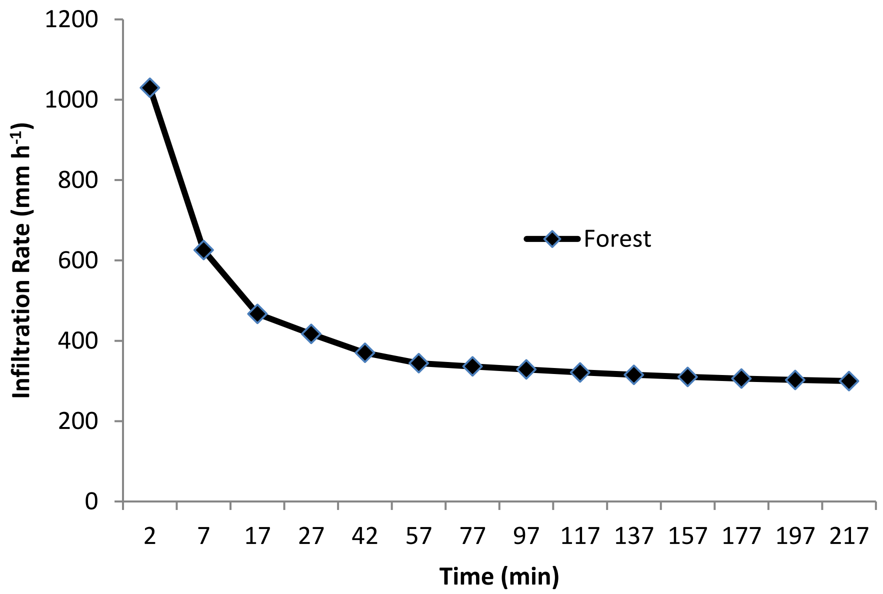

Figure 6. Soil water infiltration rate in the forest area.

According to Marcatto and Silva (2015), the good conditions of permeability in the forest, compared to other crop systems, are due to the maintenance of natural soil conditions, without direct interference from the use and management of any type of commercial crop. The forest has often been used as a comparison parameter, due to its greater conservation of physical and water properties of soils.

The empirical parameters for the mathematical models used to explain the water infiltrations in the studied soils, and the complete equations of Horton, Kostikov, Kostiakov-Lewis and Philip adjusted for each type and soil cover can be seen in Table 4.

Table 4. Results of the empirical parameters for the mathematical models used and the Horton, Kostikov, Kostiakov-Lewis and Philip equations.

Soil use	Models	EF	R^2	RMC	AC
No-Tillage	Horton	0.92	0.93	0.008	1.03
	Kostiakov	0.85	0.96	0.06	1.26
	Kostiakov-Lewis	0.70	0.97	0.07	3.60
	Philip	0.95	0.97	-0.20	1.04
Minimum cultivation	Horton	0.89	0.95	0.04	1.25
	Kostiakov	0.85	0.95	0.12	1.91
	Kostiakov-Lewis	0.57	0.98	0.19	4.84
	Philip	0.95	0.97	-0.13	1.05
Convencional cultivation	Horton	0.96	0.98	0.01	1.26
	Kostiakov	0.94	0.98	0.03	1.37
	Kostiakov-Lewis	0.50	0.98	0.16	4.37
	Philip	0.97	0.98	-0.16	1.02
Eucalyptus	Horton	0.86	0.95	0.03	1.80
	Kostiakov	0.62	0.93	0.13	3.99
	Kostiakov-Lewis	0.11	0.97	0.34	8.68
	Philip	0.85	0.92	-0.20	1.16
Forest	Horton	0.96	0.96	0.04	1.41
	Kostiakov	0.75	0.94	0.02	2.25
	Kostiakov-Lewis	0.46	0.96	0.12	6.72
	Philip	0.92	0.96	-0.18	1.07

RMC = Residual mass coefficient; AC = adjustment coefficient; EF = efficiency.

Regarding the values of efficiency (EF), the models obtained good overall performance, among them, Philip's model stands out, presenting the best results among the equations and areas, followed respectively by the models of Horton, Kostiakov and Kostiakov-Lewis (Table 4). The correlation coefficient values (R^2) were higher than 0.92, considered high, which means a good correlation of the regressions between the estimated and observed values (Table 4). This result corroborates with Souza Netto (2011), who also obtained values higher than 0.92, thus reinforcing the representativeness in the estimates of the models' parameter. The Phillip and Kostiakov-Lewis models showed the highest correlation coefficients for the no-till and forest area, while the Horton and Kostiakov models obtained the highest correlation coefficient for the conventional and minimum cultivation areas, respectively. According to Oliveira et al. (2015), the analysis of efficiency (EF) together with the correlation coefficient (R^2) represents a concise way of evaluating model performance. Fact not observed in the present research, since the EF and R^2 did not present values that could be correlated.

It was observed that by the value of the residual mass coefficient (RMC), when using the Horton, Kostiakov, Kostiakov-Lewis equations, the final infiltration rate may have been underestimated, a fact indicated by the positive values of the RMC index. For Philip's equation, overestimated values of the final infiltration rate were observed in all treatments, which was indicated by the negative values of the CMR index (Table 4). This statistical index also confirms that the best adjustment of the equation was for Horton, as it presented deviations closer to zero in all areas. Tomasini et al. (2010), in the study of water infiltration into the soil in areas cultivated with sugarcane under different harvesting systems, stated that the best adjustment of the data was for the model of Philip's equation. It should be considered that the differences in forecasts can be attributed to several assumptions of the model and field conditions, especially the soil moisture background (Bamutaze et al. 2010). The best values of the adjustment coefficient (AC) came from Philip's mathematical equation, this can be proved by the value closest to 1.

There was significant interaction ($p<0.05$) between soil cover types and soil infiltration estimation models (Table 5).

Table 1. Summary of the analysis of variance for soil water infiltration depending on the types of soil cover and different estimate models.

Source of variation	**Degree of freedom**	**Average square**
Soil cover (SC)	4	162478.45**
error 1	10	359933.75
Models (MOD)	4	2028.76**
SC*MOD	16	254.93*
error 2		108.18
Total Adjusted	74	
CV 1 (%)	46.38	
CV 2 (%)	8.04	

* and ** significant by the F test at 5% and 1% probability, respectively.

There were significant differences between forest (F), No-Tillage (NT), Minimum Cultivation (MC), Eucalyptus (EU) and Conventional Cultivation (CC) areas, but both did not differ (Table 6).

Table 2. Average values of basic infiltration rate in forest (F), No-Tillage (NT), Minimum Cultivation (MC), Eucalyptus (EU) and Conventional Cultivation (CC) areas.

Models for estimation of soil water infiltration (mm h^{-1})	**Types of use and ground cover**				
	F	**NT**	**MC**	**EU**	**CC**
Kostiakov-Lewis	285.08aA	245.84aB	91.28aC	51.78aD	49.05aD
Infiltrometer cylinder	273.00aA	220.00bB	82.00aC	50.00aD	42.00aD
Horton	273.00aA	220.00bB	82.00aC	50.00aD	42.00aD
Kostiakov	238.54bA	208.21bB	70.16abC	39.75aD	39.00aD
Philip	231.45bA	219.63bA	57.72bB	30.69aBC	41.77aC

Averages followed by the same capital letter in the same line (unfolding of the crops within each infiltration model) and lower case in the same column (unfolding of the infiltration models within each coverage type) do not differ by Tukey's 5% probability test.

The results of this research differed from those found by Cunha et al. (2015) who concluded that the no-tillage system was statistically similar to the conventional cultivation and both differed statistically from the minimum cultivation.

There was a significant effect at 5% probability for forest and eucalyptus, with a higher infiltration rate in the forest area. Romeiro et al. (2014) obtained a higher infiltration rate for the forest and a lower infiltration rate for eucalyptus, also statistically differentiated by Tukey's 5% probability test. Bonini (2012), studying degraded areas in recovery found that the forest area showed a higher soil water infiltration rate than in treatments that were modified by anthropic action. Soils with plant cover tend to have a higher infiltration rate, due to factors such as the presence of channels formed by roots, presence of organic matter and microbiological activity (Bonini and Alves 2012; Bonini 2012; Brandão et al. 2009).

The results obtained by the infiltrometer cylinder when compared to the Kostiakov-Lewis model, showed that the performance between curves were different at the beginning of the infiltration, presenting lower values than measured, but it was observed that the curves remained similar until the end of the test. These results are not in accordance with those of Pertussatti et al. (2011), studying water erosion and water infiltration under different types and soil cover, stated that the Kostiakov-Lewis model was the one that obtained the best fit for soils in studies.

Philip's model underestimated the basic soil water infiltration rate compared to the data obtained by the infiltrometer cylinder. Contrary to these results obtained for Philip's model, Gomes Filho et al. (2018) observed better results for the said model in the adequacy of the soil water infiltration rate in an area cultivated with corn and sunflower, guandu, millet and crotalaria as antecedents crops.

There was a significant effect ($p<0.05$) for no-tillage and conventional cultivation (Table 6).

The Kostiakov model underestimated the values found by the infiltrometer cylinder both at the beginning and at the end of the tests. There was a significant difference in the Kostiakov model compared to the infiltrometer cylinder test in all areas except the conventional cultivation system, this may be associated with the limitation of this model in determining the basic soil water infiltration rate in long term test. Cunha et al. (2015) when investigating the water infiltration rate in a Latosolo, concluded that the Kostiakov model was the one that best described the soil water infiltration rate.

The Horton model was the one that produced the infiltration rate of water into the soil that best fitted those obtained by the infiltrometer cylinder, since the curves became practically identical in all areas. There was no significant difference in all treatments at 5% probability when comparing the Horton model with the data obtained by the infiltrometer cylinder, thus it was possible to state that the Horton equation was perfectly adherent and best expressed the infiltration rate in all areas of this study, which was observed by other authors in a study of soil water infiltration described through mathematical models. (Santos 2014; Schreiner et al. 2010; Tomasini et al. 2010).

4. Conclusions

The different uses of the types of management and soil cover (forest, no-tillage, minimum cultivation, conventional cultivation and eucalyptus) provided different infiltration rates, with the treatment of the forest providing the highest infiltration rate while the conventional planting provided the lowest water infiltration rate in the soil of the Poxim River basin.

No-till areas provided higher values of soil water infiltration rate compared to those of minimal and conventional cultivation, contributing to a greater recharge of the water table.

Horton's mathematical equation has better adapted to the edaphoclimatic conditions of the Poxim River basin.

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